EU-Citizen.Science: A Platform for Mainstreaming Citizen Science and Open Science in Europe

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ABSTRACT

Citizen Science (CS) is a prominent field of application for Open Science (OS), and the two have strong synergies, such as: advocating for the data and metadata generated through science to be made publicly available [1]; supporting more equitable collaboration between different types of scientists and citizens; and facilitating knowledge transfer to a wider range of audiences [2]. While primarily targeted at CS, the EU-Citizen.Science platform can also support OS. One of its key functions is to act as a knowledge hub to aggregate, disseminate and promote experience and know-how; for example, by profiling CS projects and collecting tools, resources and training materials relevant to both fields. To do this, the platform has developed an information architecture that incorporates the public participation in scientific research (PPSR)—Common Conceptual Model[①]. This model consists of the Project Metadata Model, the Dataset Metadata Model and the Observation Data Model, which were specifically developed for CS initiatives. By implementing these, the platform will strengthen the interoperating arrangements that exist between other, similar platforms (e.g.,

BioCollect and SciStarter) to ensure that CS and OS continue to grow globally in terms of participants, impact and fields of application.

1. INTRODUCTION

The Citizen Science (CS) landscape is growing rapidly, gaining new actors and expanding into more diverse fields. National initiatives to promote and develop CS are emerging in many countries, and its scientific, societal and political impacts are becoming more widely recognized. This is evident in the European Union's (EU) Horizon 2020 program, which has seen the number of projects funded under its Science with and for Society (SwafS) stream rise from 21 in 2014 to 35 in 2019 [3]. This growth has largely been uncoordinated, however, and taken place without a shared agenda—and this creates challenges. For example, it has led to a huge range of approaches, tools, resources, projects and impacts. While this diversity is welcome, it can result in duplicated efforts, or make it difficult for newcomers to navigate the range of methods and approaches found across different disciplines, sectors and regions.

While CS is grounded in the scientific process, CS approaches to research often require considering additional factors ranging from the ethical engagement of volunteer communities to tailed data quality practices. To address the unique practices associated with CS, the EU-Citizen.Science platform② was created as a central place to exchange experiences, gather information and network around CS—and wider Open Science (OS) practices. This three-year EU-funded project (2019–21) is being led by a consortium of 21 partners from universities, non-governmental organizations (NGOs), local authorities, civil society organizations, small and medium-sized enterprises and natural history museums. The platform's alpha version was released in March 2020 as a mutual learning space where CS tools and resources, best practice examples and project profiles are collected, curated and made available for anyone interested in CS, such as researchers (including those not current leveraging CS), public citizens, the media, scientific institutions, policy-makers and funding bodies. By 2021, EU-Citizen.Science aims to be the central knowledge-sharing hub for CS in Europe. Section 1.1 provides a fictional example of how EU-Citizen.Science can be used to find projects and resources.

By advocating for, and supporting efforts to realize greater citizen involvement in science, EU-Citizen.Science supports many aims of OS. The ethos described in the 10 principles of CS [4] is a key foundational reference point for the platform, and is consistent with and supportive of the central aims of OS for transparency, accessibility, sharing and collaborative inclusion. For example, involvement in CS projects can enhance public interest in science [5].

It is important to note that unlike open repositories for documents and data such as B2SHARE, Zenodo, or OSF, EU-Citizen.Science does not host any data gathered by CS initiatives; it only gathers descriptive metadata for projects and resources, along with the open-repository-generated DOI to signpost the hosted

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② https://eu-citizen.science

location of the resource, or permalink to the project. EU-Citizen.Science does, however, provide guidelines for making citizen-generated data publicly available and, where possible, published in an open-access format. In keeping with the FAIR principles (findable, accessible, interoperable, and reusable) for data handling and processing, and to ensure the interoperability of the platform with other CS platforms, and to enable the exchange of information about projects and resources via an application programming interface (API), EU-Citizen.Science has implemented: (1) the Project Metadata Model to describe CS projects, (2) the Digital Documents ontology from Schema.org (with vocabulary from Dublin Core) to describe CS resources, and (3) the Courses ontology from Schema.org to describe CS training materials. This information architecture not only supports such network collaborations; it also greatly aids the platform's search functions for users.

This article first explains how the two fields of CS and OS intersect (Section 2), and then explores the information architecture behind the platform in detail (Section 3). It concludes by considering the challenges the platform faces (Section 4) and plans for its future use and development (Section 5).

1.1 EU-Citizen.Science in Use: A Practical Example

Sally and James plan to set up an NGO to monitor air quality in their town. They want to know if there are similar initiatives in Europe that could provide them with a starting point. On EU-Citizen.Science, they search for projects and resources that include the term "air quality" in their metadata. Their search yields several results, including D-NOSES③, a project about odour pollution. On the platform, they can read about the project's aims and discover its free-to-use tools: the OdourCollect app④ and the International Odour Observatory⑤. Data already collected through D-NOSES is openly accessible on the D-NOSES app, alongside open-access information and resources to further their knowledge on how citizens can monitor odour pollution. Through EU-Citizen.Science, Sally and James can also connect with other CS projects, providing them with a wealth of experience and knowledge to build upon. This helps to kick-start their own initiative and they use the open-access tools, which have been tested by others, to start collecting data on odours in their region. Once their own NGO has been set up, they add it as a new project to EU-Citizen.Science, using relevant metadata to ensure that others can find them in the same way they found D-NOSES.

2. CS AND OS

2.1 A Brief Overview of CS

While CS has a tradition dating back centuries [6], the concept was not formally established until the 1990s. Two of the definitions developed then are still applicable today. Bonney [7] defined it as projects in which non-professional scientists voluntarily contribute scientific data to professionally led research projects, while Irwin [8] described it as a way of developing concepts of scientific citizenship, and opening up science and science policy processes to the public.

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③ https://dnoses.eu/

④ https://odourcollect.eu/

⑤ https://odourobservatory.org/

These early definitions highlight the continuing challenge in pinning down exactly what CS is. While Bonney focuses on the acceleration of research through new data, and gains in topical knowledge by citizens, Irwin prioritizes participation, the opening up of science and two-way knowledge exchange. This relative ambiguity about CS is further complicated by the numerous terms and typologies that have emerged in recent years, which include, among others: community science, civic science, people-powered science, volunteered (or crowd-sourced) geographic information, community remote sensing, citizen observatories, crisis mapping and citizen-generated data[⑥].

Indeed, Haklay et al. [9] attest to reluctance within the CS community to establish a uniform, binding definition: rather, actors are more interested in an open discussion about which criteria and practices describe many phenomena incorporated within CS. This dynamic, flexible approach allows for constant development and adaptation, and also means that CS—and its definitions—encompass and promote an open understanding of the diverse research practices and participatory activities it can include. Yet this heterogeneity of terms, approaches and understandings makes it all the more important to develop a common metadata standard for the field, one that builds a shared frame of reference independent of designation and discipline.

2.2 Where CS and OS Intersect

CS and OS are related paradigms that have seen recent growth in practical activities and policy support. The Organization for Economic Co-operation and Development [12] defines OS as "efforts to make the output of publicly funded research more widely accessible in digital format to the scientific community, the business sector, or society more generally". There have been dedicated efforts to explore the connections between OS and CS. A policy brief by DITOs Consortium by 2018 [13] performs an analytical consideration of the relationship between the two fields, and identifies key synergies and shared challenges, such as diversity and inclusion, education and training, funding, and incentives or rewards. The authors portray them as complementary, overlapping approaches, and identify the "accessibility of research results and processes" as a shared central tenet (Figure 1).

Hecker et al. [11] also locate CS in the immediate environment of OS, specifically as a rapidly growing field in OS and open innovation. This conceptualization suggests a slightly different relationship between the two terms (Figure 2), where CS falls under the broader OS, or open innovation, umbrella[⑦]. Common to both definitions is the emphasis on common areas, including broadening access to research and data (Section 2.3 provides an example of this).

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⑥ Eitzel et al. [10] and Hecker et al. [11] provide longer discussions of what CS is, and what the different terms related to the field may entail.

⑦ While Citizen Science (CS) is often considered a component of OS in Europe, key US policy developments, particularly during the Obama Administration, address CS under the umbrella term of "open innovation".
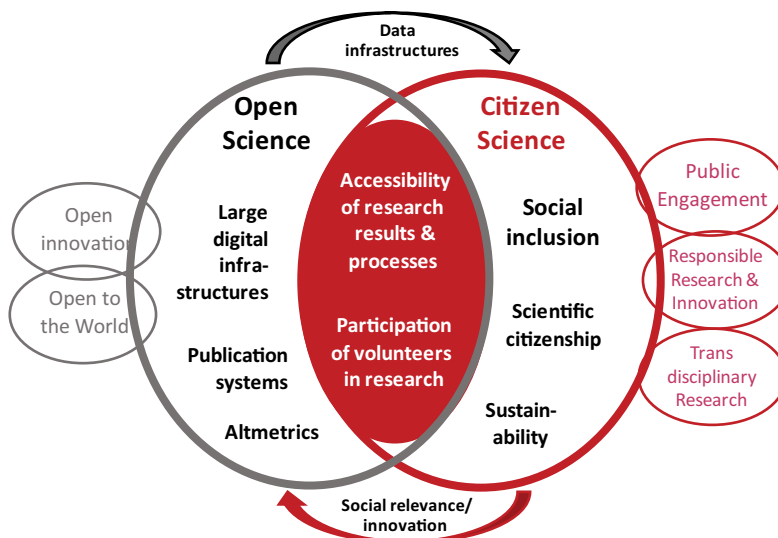
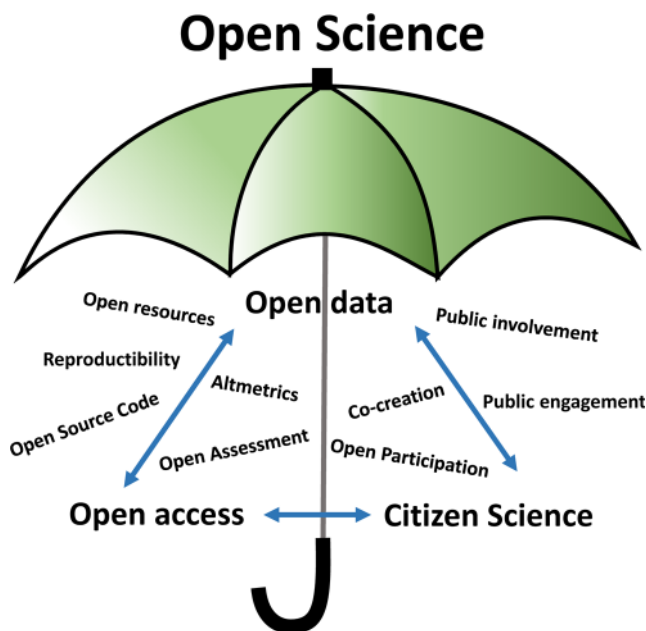**Figure 1.** Open Science and core concepts and areas of synergy. Note: Source: Vohland and Göbel [14].

Figure 2. Open Science as an umbrella concept. Note: Source: Figure made by Lotta Tomasson, VA CC BY-NCE 2.0, in paper Wehn et al. [15].

In 2020, the CS and OS Community of Practice collaborated on a whitepaper®. A major finding was that CS can strengthen OS through an emphasis on process, particularly by contending with the opportunities and challenges of involving a much wider range of stakeholders than traditional OS may allow. This includes several key elements. The OS approach to **open access** often focuses on making the outputs and processes of academic research more open and available by improving existing processes. In CS, open access is also seen as a valuable way to gain greater knowledge about a research topic, and therefore participate more comprehensively in a research study. **Open Data** (OD) is a second key element. In general, OS has a more advanced technical infrastructure to support the collection and management of open and FAIR information. CS, meanwhile, is required to consider the ethics of OD, for example privacy concerns.

In CS, **open software and hardware** are important not only for enabling more professionally led research, but also to democratize the tools of science and enable more diverse public stakeholder groups to participate in or lead research activities. The same is valid for **Open Educational Resources (OER)**, which include many open access, OD, and open software and hardware tools designated for educational purposes. In OS generally, OER suggests that high quality educational tools should be made available to a large number of learners. In CS, there is also an emphasis on the diversity of educational tools, to encompass both teaching aids (e.g., lesson plans) and resources for informal or individual learning (e.g., tutorials or instructional videos).

2.3 Ensuring Citizen-generated Data Are Open

Opening up science and research processes to greater participation by citizens increases the awareness and uptake of, and interest in, scientific results and outcomes; it can also lead to larger volumes of data [16]. To ensure citizen-generated data are open and accessible, and their long-term storage, management and secondary use are not dependent on institutional support, several OD management and storage services are being established. A leading initiative is the European Open Science Cloud (EOSC) [16].

Since 2018, the EOSC has aimed to accelerate the deployment and consolidation of an open, trusted, virtual, federated environment in Europe to store, share and reuse research data across borders and scientific disciplines, and to provide access to a wide range of related services. Within the field of CS, the EU-funded Cos4Cloud project® is building upon the experience of citizen observatories, and especially the technological challenges they have faced in offering new or improved services, to increase the quantity and quality of CS data within the EOSC framework. In this way, Cos4Cloud is, like EU-Citizen.Science, supporting and promoting the growth and impact of CS and OS. Many CS projects also share their data via domain-specific repositories, such as the Global Biodiversity Information Facility for biodiversity data.

® This whitepaper was a response to the global consultation to support the development of a Recommendation on Open Science, launched by the United Nations Educational, Scientific and Cultural Organization (UNESCO), which shall be adopted by the UNESCO General Conference in 2021.

® https://cos4cloud-eosc.eu

3. THE VALUE OF METADATA IN EU-CITIZEN.SCIENCE

For EU-Citizen.Science, the key to aggregating and further disseminating open tools, resources, data and training effectively, and to a broad audience, was to implement a well-structured information architecture and data layer within the platform: one that supports a logical content structure, useful content filtering, relevant keywords and an effective global search function. The platform's metadata structure plays a crucial role in the discovery and findability of its content, and assists the users in identifying content relevant to their needs.

3.1 How EU-Citizen.Science Uses Metadata

Given the nature of EU-Citizen.Science—as a signposting knowledge hub that profiles content hosted or stored elsewhere—its metadata models focus on basic descriptive information, such as: the title and author of resources; keywords to describe the content; and enriched information that is context and content specific. This enhances the platform's value to the CS and OS communities. The implemented ontology provides the formal naming of categories, their definitions, and their inter-relationships, which are thus the subject of the metadata. The goal of having ontologies is to share knowledge more easily, by organizing content in a system that reduces complexity according to terminology and typologies that have been agreed upon by the fields of CS and OS. The main ontology components relevant to the platform are class ontologies (types of content) and attribute ontologies (aspects, properties, features and characteristics of the content). The three relevant content class ontologies for EU-Citizen.Science are: CS resources, CS training materials, and CS projects.

3.1.1 Metadata for CS Resources

For the description of resources, the platform looks to the Dublin Core Metadata Initiative schema®, which is specifically designed to describe creative content such as digital resources (e.g., video, images, Web pages), physical resources (e.g., books, CDs) and physical objects (e.g., artworks). The platform uses the Dublin Core controlled vocabularies, such as those for "resourceType", in combination with the ontology proposed by Schema.org for CreativeWorks⑪ and Things⑫. Schema.org vocabulary can be used with many different encodings, including RDFa, Microdata and JSON-LD. These vocabularies cover entities, relationships between entities and actions, and can easily be extended through a well-documented extension model. This provides EU-Citizen.Science with interoperability potential across a wide range of linked data cloud and semantic Web implementations.

According to Schema.org⑬, over 10 million sites use their standard to markup their Web pages and email messages. Founded by Google, Microsoft, Yahoo and Yandex, Schema.org vocabularies are developed by

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⑩ http://dublincore.org
⑪ https://schema.org/CreativeWork
⑫ https://schema.org/Thing
⑬ https://schema.org

an open community process and are maintained by the Schema.org initiative. Within these, the Resource Description Framework (RDF) is a specification developed and maintained under the auspices of the W3C®. The RDF schema provides mechanisms for describing groups of related resources and the relationships between these resources. Using this schema within the information architecture of the platform enhances its interoperability with other such platforms and resources, and any future potential linked data cloud or semantic Web implementations.

3.1.2 Metadata for CS Training Materials

Although training materials can be described using the Dublin Core metadata for resources outlined above, they also require specific metadata fields that relate more specifically to their educational character and purpose, such as training videos and Massive Online Open Courses. For training materials profiled on the platform, the Schema.org Course® metadata was used to describe educational courses, education offered through different media or modes of study, educational events, and/or creative works that aim to build the knowledge, competence or ability of learners; and the Dublin Core LRMI terms® developed to markup and describe educational resources. This builds on the extensive vocabulary provided by Schema.org and other standards to increase the platform's value and interoperability.

3.1.3 Metadata for CS Projects

For the description of projects, the platform implemented the PPSR—Common Conceptual Model (see Section 3.2), which consists of the Project Metadata Model (PMM), the Dataset Metadata Model (DMM) and the Observation Data Model (ODM). The PMM captures information primarily at the CS project level, including research topic, audience and intended outcome. The DMM documents considerations such as intellectual property concerns. The ODM is being developed in tandem with work on the Open Geospatial Consortium Sensor Things API standard, and also takes into consideration existing metadata standards, particularly Dublin Core.

The PPSR—Common Conceptual Model® specifically describes CS projects, providing a shared vocabulary for a range of metadata fields. Implementing the PMM empowers EU-Citizen.Science's interoperability and enables it to enter into collaborative data-sharing aggregation networks with other key regional platforms, such as BioCollect®, SciStarter® and the EU's Joint Research Center repository of CS projects®.

® www.w3.org/TR/rdf-schema

® https://schema.org/Course

® www.dublincore.org/specifications/lrmi/lrmi_terms

® https://core.citizenscience.org/

® www.ala.org.au/biocollect

® https://scistarter.org

® https://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004

3.14 Metadata for CS Data

Although the EU-Citizen.Science platform does not serve as a repository for data that have been generated by citizens participating in CS initiatives, it is worth noting that the PPSR DMM does provide a schema for describing how observations are collected, how those data may be used, and other information on the data as a whole; and the PPSR ODM provides a schema for describing the structure of individual observations including: location, date, observer, and attributes specific to the research.

3.2 How the PPSR—Common Conceptual Model Was Developed

In 2010, DataONE, funded by the US National Science Foundation, chartered a working group on a PPSR conceptual model. Under the umbrella of an organization devoted to increasing scientific data sharing, the PPSR working group focused on a handful of projects, which included identifying relevant metadata standards for CS. Meanwhile, at the inaugural meeting of the Australian Citizen Science Association in 2015, researchers from Australia, Europe and the US came together to discuss challenges associated with data sharing and interoperability. The culmination was an agreement to co-found a "Data and Metadata" working group within the US-based Citizen Science Association (CSA). Many representatives of the DataONE PPSR working group quickly joined.

Since these developments, the CSA Data and Metadata working group has become the primary driver behind the conceptual model. Since 2015, it has been developed by an international group of CS researchers and practitioners, from the CSA's "Data and Metadata" working group, the European Citizen Science Association's (ECSA) "Projects, Data, Tools, and Technology" working group, and the European COST Action on Citizen Science's working group to "Improve data standardization and interoperability". This work has been further supported by a project funded by the Alfred P. Sloan Foundation.

4. CHALLENGES FOR THE EU-CITIZEN.SCIENCE PLATFORM

4.1 How to Remain up to Date and Relevant

As with all technology-based projects, EU-Citizen.Science will face a continuous challenge to remain up to date. In this case, however, the challenge is not limited to new technological developments; the platform will also have to remain relevant to the fields of both CS and OS—which, as noted in Section 2, are constantly evolving. The platform's metadata model will play a key role here. Its robustness for wider use within these fields will also be tested; it will need to prove it works for imprecise and moving targets, and that it can help users with differing needs and priorities to find what they are looking for.

Another measure to help in this regard is the constant feedback loops that have been built into the platform's development, which will remain an operational feature moving forward. By communicating regularly with the platform's users, and with the wider CS and OS communities, it should be possible for the platform to maintain a searchability that is fit for purpose. Indeed, EU-Citizen.Science should initiate such discussions.

However, not all CS and OS projects are familiar with the need for metadata; nor is it always a priority for projects, especially those run largely by volunteers or those facing time and budget limitations. The platform may need to advocate for the importance of robust metadata to remain relevant: Its function as the best place to find projects and resources is only as strong as the metadata uploaded to it, and depends on content being kept up to date. To achieve this, it will need to maintain a user-friendly interface and continually demonstrate added value for its community.

4.2 Metadata Becoming a Burden for, or Barrier to, Users

In its initial release, EU-Citizen.Science sought a balance between a desire to gather thorough metadata for all projects, and the drop-off effect of asking for too much information (and therefore making a bigger demand on people's time). This balance is especially relevant for the platform, as its value to a wider community of citizens and researchers relies on a mix of rich information-sharing and active participation on the platform.

Looking forward, possible solutions to managing this trade-off include Metadata Description As a Service (MDaS) tools, such as the "Metadata Wizard". These tools provide a user-friendly and highly efficient environment for creating, editing, previewing and validating metadata for each project. MDaS includes tools that can automate and facilitate the creation of high-quality metadata records [17]. For EU-Citizen.Science, these could, for example: (1) automate the population of contact information for ECSA affiliates, and keywords from controlled vocabularies; (2) be a validator to highlight any missing or error elements, whether directly on a dedicated graphical user interface (GUI) and/or in a printable report suitable for metadata review; (3) be a tool to Copy/Paste or Drag-and-Drop entire sections, subsections or individual content between different records or other tools (including XML-Notepad and text editors); (4) offer built-in documentation which guides users through questions about metadata.

5. CONCLUSIONS AND FUTURE EXPECTATIONS

The EU-funded project to develop the EU-Citizen.Science platform will end in December 2021, after which it will be managed by ECSA. The platform will continue to bring greater openness to science: by facilitating the sharing and reuse of, and access to, critical resources; by bringing clarity and order to the ever-growing number and diversity of projects that fall under the umbrellas of CS and OS; by capturing information about the accessibility and licensing of resources and training materials; by signposting users to OD assets generated by projects; and by highlighting the availability of open access publications, open hardware and software, and OER.

To increase its relevance for OS further, the platform should strengthen its links with open access e-infrastructures, particularly within the EOSC framework. Another important role will be to demonstrate the benefits of implementing a FAIR-based platform, lastly, the EU-Citizen.Science platform should increase its advocacy for CS and OS. As well as gathering and curating projects, tools and other resources, it can be a "mouthpiece" for the many benefits of CS and OS: for research and researchers, for project participants,

and for society more widely. This can be achieved by initiating and moderating discourse and discussions between all the key stakeholders (especially the policy audience), sharing success stories, and establishing itself as the central platform for CS and OS—in Europe and beyond.

AUTHOR CONTRIBUTIONS

K. Wagenknecht (katherin.wagenknecht@gmail.com) drafted Sections 1.1, 1.3 and 2.1. T. Woods (tim. woods@mfn.berlin) drafted the abstract and Sections 4 and 5. A. Bowser (Anne.Bowser@wilsoncenter.org) drafted Sections 2.2 and 3.2. M. Gold (mg@margaretgold.co.uk) drafted Section 3.1. S. Rüfenacht (simone. ruefenacht@mfn.berlin) drafted Section 1.2. L. Ceccaroni (lceccaroni@earthwatch.org.uk), J. Piera (jpiera@ icm.csic.es) and F. Sanz García (frasanz@bifi.es) provided inputs throughout, notably regarding metadata schema, the PPSR—Common Conceptual Model and the EOSC initiative. All authors made meaningful and valuable contributions to revising and improving the manuscript.

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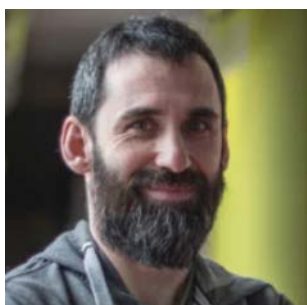
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